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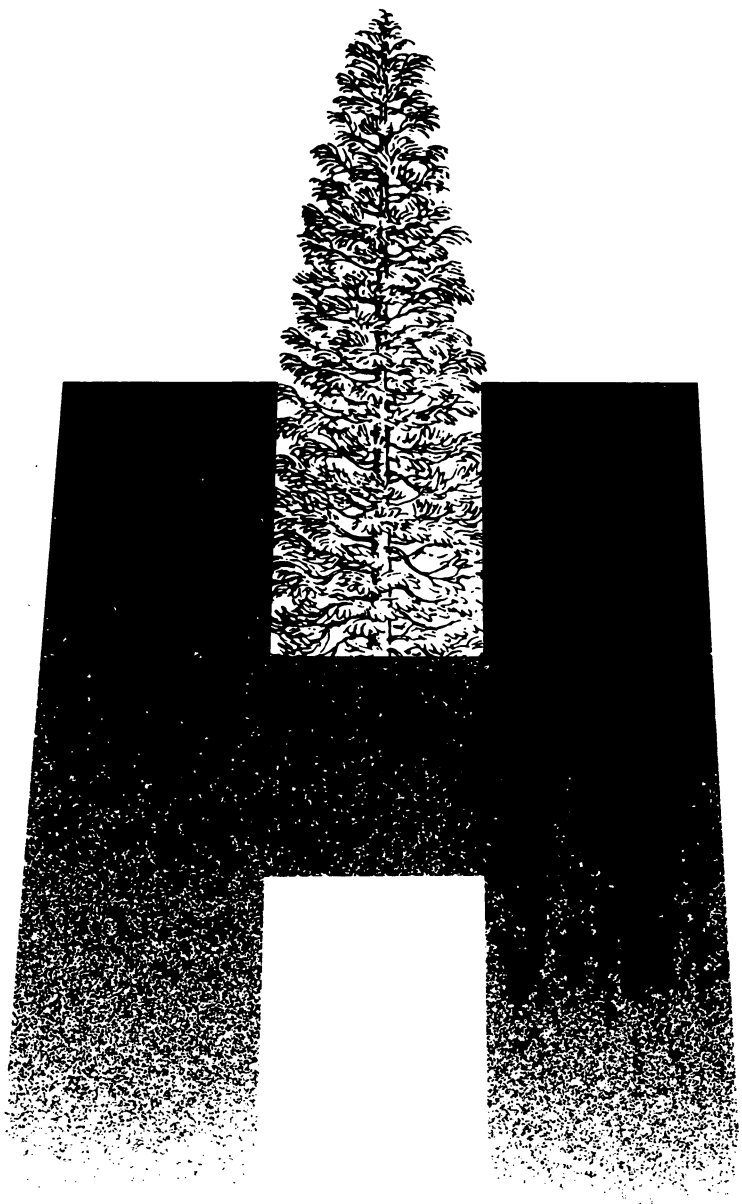

North Central Forest Experiment Station
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USING GLYPHOSATE HERBICIDE IN CONVERTING ASPEN TO CONIFERS

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Glyphosate--N-(phosphonomethyl) glycine--is a broad-spectrum foliar active herbicide gaining international popularity for site preparation and conifer release. It is marketed by the Monsanto Company as Roundup®[1] herbicide which contains four pounds per U.S. gallon of the active ingredient, isopropylamine salt of glyphosate. Labeling for the herbicide claims good woody plant control late in the growing season, even with some fall coloration. This would be especially desirable for conifer release because most are injured by the herbicide if sprayed too early (Sutton 1978). Both conifers and competing vegetation are rate-sensitive to glyphosate (Alm 1981), but the interaction between seasonal timing and dose rates to optimize the performance of glyphosate is poorly documented.

This paper describes how glyphosate performed seasonally and at three rates mainly on quaking aspen (*Populus tremuloides* Michx.), the most common competitor of conifers on conversion sites in the Upper Great Lakes region.

METHODS

The study area is located on University of Minnesota's Cloquet Forestry Center, about 19 miles southwest of Duluth, Minnesota, in the spruce-fir forest section (Bailey 1980). The climate is humid warm-summer continental, with cold winters. July mean temperature and annual precipitation average 66°F and 27 inches. Two soil series are found on the site: Omega sandy loam (mixed, frigid Spodic Udipsamment) and Cloquet sandy loam (mixed, frigid Typic Dystrochrept). A mature stand (60 years old, site index 56) of aspen and paper birch (*Betula papyrifera* Marsh.) occupied the site. Aspen accounted for 44 percent of the total stand basal area of 83 ft² per acre. A dense shrub layer consisted mostly of hazel (*Corylus americana* Walt.) with lesser amounts of bush honeysuckle (*Diervilla lonicera* Mill.) and minor amounts of other species.

The area was clearcut (half full-tree and half tree-length logged) in the summer of 1979 and regenerated profusely to aspen suckers the next year. During late summer 1980, glyphosate was broadcast on foliage at rates of 0 (control), 1.0, 1.5, and 2.0 lbs a.i. per acre on each of four dates between August 8th and September 17th. A powered backpack sprayer was used to deliver the herbicide at a total aqueous volume of 10 gallons per acre to square plots 3000 ft² in area. Each treatment combination was replicated four times. Spraying commenced at 8:30 a.m. and was completed no later than 11:20 a.m. CST on each date. Spraying weather seemed favorable (table 1).

In late August and early September, 1981, vegetation on each plot was inventoried, summarized, and expanded to an area basis using the method of nonoverlapping triangles (Loetsch *et al.* 1973). Dominant and codominant aspen suckers (whether dead or alive) defined the corners of the triangles (five per plot). Live suckers were measured for total height (h, feet) and basal diameter (d, inches at 1 foot). Other live aspens, hardwoods, and shrubs were counted within each triangle. Herbaceous cover percent was estimated by eye on each triangle and up to three dominant species recorded. An index of biomass, $d^2 h$, was computed for

Table 1.--*Spraying weather, Cloquet, MN, 1980*

Date	Wind	Temperature		Sky	24-hr ppt[1]
		Minimum	Maximum		
	Mph	- - - - - °F - - - - -			*In.*
Aug 8	10	62	80	clear	0
Aug 22	5-10	52	79	clear	0.25
Sept 2	5	50	70	clear	1.47
Sept 17	2	33	56	cloudy	0.09

[1]Rain that fell in the 24-hour period beginning at 3:00 p.m. on the spraying date. No rain fell between spraying completion and 3:00 p.m.

[1]*Mention of trade names is for the convenience of the reader and does not constitute endorsement by the USDA Forest Service over other products equally suitable.*

the dominant and codominant aspens. Total aspen d^2 h was estimated from a cumulative d^2 h/stem-number function[2]. Total aspen biomass was estimated from total d^2 h (Perala 1973).

The 2.0 lb rate of glyphosate was also applied on August 12 and 13, 1980 to another site on the Ottawa National Forest, 16 miles south-southeast of Ontonagon, Michigan. This site is in the northern hardwoods-fir forest section (Baily 1980) with climate similar to Cloquet--mean July temperature is 66°F and annual precipitation totals 32 inches. The soil series on this site is Ontonagon silty clay (mixed, Glossic Eutroboralf). A mature stand (age 47, site index 59) of quaking aspen (51 percent of total basal area) and northern hardwoods, principally sugar maple (*Acer saccharum* Marsh.) and American basswood (*Tilia americana* L.) dominated this site with 108 ft^2 of basal area. The shrub layer was relatively sparse.

This site was clearcut (whole-tree and tree-length logged) during late winter 1980 and regenerated the following summer to a dense thicket of aspen suckers and hardwood sprouts. Five acres were sprayed and five acres left unsprayed altogether on four blocks. Vegetation inventory was similar to Cloquet except that shrub and herb data were not gathered.

The data were analyzed as a randomized block design with parent aspen basal area as a covariate to remove the expected background variability in aspen suckering. Differences between the Cloquet data treatment combination means were tested for significance using Duncan's new multiple-range test (Steel and Torrie 1960).

On-site measured rainfall totaled 10.9 and 13.5 inches for the Cloquet and Ontonagon sites during June-August, 1980. This is about 7 and 24 percent above normal.

Both sites were planted with container grown (Ray Leach Pine Cells) white spruce (*Picea glauca* (Moench) Voss) in the spring of 1981. Survival was evaluated 2 years later.

RESULTS

At Cloquet, glyphosate regardless of rate significantly reduced aspen biomass and aspen and shrub stem density through September 2nd (tables 2 and 3). Results for September 17th were highly variable, ranging from significant shrub control to non-significant reduction in aspen stems. No treatment significantly controlled hardwoods. Herbaceous cover was less (but not significantly) in the treated plots than in the untreated (table 4). The frequency of grasses and sedges, large-leaved aster (*Aster macrophyllus* L.) and northern dewberry (*Rubus flagellaris* Willd.) tended to increase, and that of bracken fern (*Pteridium aquilinum* (L.) Kuhn), raspberry (*Rubus idaeus* L.), northern bead-lily (*Clintonia borealis* (Ait.) Raf.), wild sarsaparilla (*Aralia nudicaulis* L.), and strawberry (*Fragaria virginiana* Duchesne) tended to decrease on the treated plots (table 4). Overall, 1.5 or 2.0 lbs per acre of glyphosate on August 22nd were the most consistent and effective treatments in reducing aspen biomass, woody stem density, and important herbaceous competitors such as bracken fern and raspberry.

At the Ontonagon site, woody plant control was significant but not as good as at Cloquet. Aspen biomass was reduced by only 69 percent, and aspen stem count by 44 percent. Hardwood stems were 20 percent more numerous on the sprayed plots. Dominant aspen mean d^2 h was reduced by 55 percent at both sites. Survival

[2]*On file, Forestry Sciences Laboratory, Grand Rapids, MN.*

Table 2.--*Aspen biomass, as percent of unsprayed control (3,040 lbs per acre), one year after spraying glyphosate at three rates on four dates; Cloquet*

Rate (Lbs/ac., a.i.)	Date and Growing Degree-Days[1]				
	August 8 (2323)	August 22 (2638)	September 2 (2883)	September 17 (3126)	Mean[2]
	- - - - - - - - - - *Percent of control*[3] - - - - - - - - - -				
1.0	9^c	9^c	8^c	40^{bc}	8
1.5	8^c	3^c	10^c	15^c	7
2.0	5^c	10^c	9^c	91^{ab}	8
Mean	8	7	9	49	8

[1]Accumulated mean daily temperature exceeding 40°F.
[2]Without September 17.
[3]Values with the same letter do not differ significantly (p/gr 0.05). Value with letter "a" not significantly different from zero rate.

Table 3.--*Number of woody stems per acre one year after spraying glyphosate at three rates on four dates; Cloquet*

Rate (Lbs/ac., a.i.)	Date				
	August 8	August 22	September 2	September 17	Mean[1]
			Stems per acre[2]		
ASPEN					
1.0	3,225[b]	3,070[b]	2,923[b]	10,930[ab]	3,073
1.5	2,867[b]	3,069[b]	3,822[b]	5,389[ab]	3,253
2.0	2,068[b]	3,600[b]	3,758[b]	19,288[a]	3,142
Mean	2,720	3,246	3,501	11,869	3,156
HARDWOODS					
1.0	2,828[a]	1,049[a]	166[a]	4,629[a]	1,348
1.5	789[a]	276[a]	3,656[a]	2,234[a]	1,574
2.0	510[a]	438[a]	1,854[a]	3,278[a]	934
Mean	1,376	588	1,892	3,380	1,285
SHRUBS					
1.0	15,916[bc]	3,714[c]	19,649[bc]	24,608[b]	13,093
1.5	7,143[bc]	6,942[bc]	4,478[c]	13,382[bc]	6,188
2.0	2,461[c]	4,676[c]	3,120[c]	12,065[bc]	3,419
Mean	8,507	5,111	9,082	16,685	7,567

[1]Without September 17.

[2]Values with the same letter do not differ significantly (p/gr 0.05). Values with letter "a" not significantly difference from zero rate (18,900, 2,440, and 40,700 stems per acre for aspen, hardwoods, and shrubs, respectively).

of container-grown white spruce after 2 years did not differ significantly by site or treatment, as seen in the following tabulation.

Site	Glyphosate	Control
	— (Percent survival) —	
Cloquet	77	82
Ontonagon	77	78

DISCUSSION AND CONCLUSIONS

Vegetation on aspen dominated sites can be controlled with glyphosate with equal effectiveness over a period of about a month beginning the second week in August, or from about 2300-2900 GDD (growing Degree Days, 40°F threshold). Aspen was not rate sensitive from 1.0 to 2.0 lbs a.i. per acre, but 1.5 to 2.0 lbs are needed to control shrubs and susceptible hardwoods such as paper birch. The higher rates are more effective probably because they better penetrate the taller aspen canopy. Glyphosate provides only temporary control of the herb community. While the apparent shift in species composition away from bracken fern and especially raspberry is advantageous to conifer survival and growth, the shift to sedges and especially grasses is disadvantageous.

Why the September 17th treatment was inferior cannot be explained. Climatic stress does not seem to be a factor although temperatures were seasonably cool--highs generally in the 50's and low 60's for the remainder of the month. Soil moisture was not inordinately limiting given the above normal summer precipitation, and frost did not occur until 25°F was recorded at the Cloquet Forestry Center on September 26th. Aspen suckers in particular had little fall coloration at least till then. It appears that control of aspen dominated sites with glyphosate after the first week or so in September might be unreliable unless limiting climatic or physiological factors can be identified.

Table 4.--*Herbaceous community summary one year after spraying glyphosate at three rates on four dates; Cloquet*

Rate		Frequency[1]	
(Lbs/ac.,a.i.)	Cover	Increasers[2]	Decreasers[3]
		Percent	
0	77	128	87
1.0	68	164	40
1.5	70	163	38
2.0	67	176	40
Date:[4]			
August 8	68	175	41
August 22	69	163	22
September 2	75	165	56
September 17	61	142	40

[1]Sum of individual frequencies.
[2]Grass and sedge, large-leaved aster, northern dewberry.
[3]Bracken, raspberry, northern bead-lily, wild sarsaparilla, strawberry.
[4]Zero rate not included.

Although vegetation control at the Ontonagon site was not as good as at Cloquet, it was still sufficient to provide 3 to 4 years of relatively unrestricted conifer growth before a release is needed. Control was much more erratic at Ontonagon despite applying only one rate during an optimum spraying period. The one block that was sprayed there on August 13th was particularly poor because rain started almost immediately after spray completion (this block was not included in analysis). Glyphosate labeling cautions against such mishap and suggests that retreatment may be necessary. On the remaining blocks, control was so complete in some patches that they became dominated by fireweed (*Epilobium angustifolium* L.). In contrast, sugar maple, which is extremely difficult to control, dominated where it was abundant. That aspen was relatively poorly controlled at Ontonagon suggests intersite variability in the efficacy of glyphosate.

It is not surprising that spruce survival was unaffected by glyphosate site preparation. The herbicide is quickly inactivated in the soil and offers minimal possibility of root uptake. And 2 years is not long enough to demonstrate the effect of competition control on survival. What is unexpected, however, is the good survival on an Ontonagon soil which is notoriously difficult for seedling establishment.

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PESTICIDE PRECAUTIONARY STATEMENT

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Glyphosate at 1.5 to 2.0 lbs per acre active ingredient will control aspen suckers, shrubs, and herbs when applied during August to early September. There appears to be some intersite variability in the efficacy of the herbicide.

KEY WORDS: Dosage, timing, efficacy, *Populus tremuloides, Picea glauca.*

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